

1 **METHOD AND APPARATUS FOR SELECTIVE BIOLOGICAL MATERIAL**

2 **DETECTION**

3
4
5 **Reference to Related Applications:**

6 This application is a continuation-in-part of 09/550,779, filed
7 on April 17, 2000, which is a continuation-in-part of S.N.
8 09/218,827, filed on Dec. 22, 1998 and now U.S. Patent
9 6,051,388, having an issue date of April 18, 2000, the contents
10 of which are herein incorporated by reference.
11

12 **Field of the Invention**

13 This invention relates to the detection of pathogenic
14 microorganisms, or biological materials, and more particularly
15 relates to a composite bioassay material useful for the
16 detection of particular toxic substances, its method of
17 manufacture and method of use, wherein the composite material
18 is particularly useful for food packaging and the like, and is
19 capable of simultaneously detecting and identifying a
20 multiplicity of such biological materials.
21

22 **Background of the Invention**

23 Although considerable effort and expense have been put
24 forth in an effort to control food borne pathogenic

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microorganisms, there nevertheless exist significant safety problems in the supply of packaged food. For example, numerous outbreaks of food poisoning brought about by foodstuffs contaminated with strains of the E-Coli, Campylobacter, Listeria, Cyclospora and Salmonella microorganisms have caused illness and even death, not to mention a tremendous loss of revenue for food producers. These and other microorganisms can inadvertently taint food, even when reasonably careful food handling procedures are followed. The possibility of accidental contamination, for example by temperature abuse, in and of itself, is enough to warrant incorporation of safe and effective biological material diagnosis and detection procedures. Further complicating the situation is the very real possibility that a terrorist organization might target either the food or water supply of a municipality or even a nation itself, by attempting to include a pathogenic microorganism or toxic contaminant capable of causing widespread illness or even death. If, by accident or design, the food supply of a particular population were to be contaminated, it is not only imperative that the population be alerted to the contamination, but it is further necessary that the particular contaminant be quickly and precisely pinpointed so that appropriate countermeasures may be taken.

Thus, if it were possible to readily substitute standard

packaging materials with a flexible material capable of

- 1) quickly and easily detecting the presence, and
- 2) indicating the particular identity of a variety of pathogenic biological materials, a long felt need would be satisfied.

Description of the Prior Art

The Berkeley Lab Research News of 12/10/96, in an article entitle "New Sensor Provides First Instant Test for Toxic E.Coli Organism" reports on the work of Stevens and Cheng to develop sensors capable of detecting E. Coli strain 0157:H7. A color change from blue to red instantaneously signals the presence of the virulent E. Coli 0157:H7 microorganism. Prior art required test sampling and a 24 hour culture period in order to determine the presence of the E. Coli microorganism, requiring the use of a variety of diagnostic tools including dyes and microscopes. An alternative technique, involving the use of polymerase chain reaction technology, multiplies the amount of DNA present in a sample until it reaches a detectable level. This test requires several hours before results can be obtained. The Berkeley sensor is inexpensive and may be placed on a variety of materials such as plastic, paper, or glass, e.g. within a bottle cap or container lid. Multiple copies of a single molecule are fabricated into a thin film which has a

1 two part composite structure. The surface binds the biological
2 material while the backbone underlying the surface is the
3 color-changing signaling system.

4 The Berkeley researchers do not teach the concept of
5 incorporating any means for self-detection within food
6 packaging, nor do they contemplate the inclusion of multiple
7 means capable of both detecting and identifying the source of
8 pathogenic contamination to a technically untrained end user,
9 e.g. the food purchaser or consumer.

10 Wang et al, in an article entitled "An immune-capturing
11 and concentrating procedure for Escherichia coli 0157:H7 and
12 its detection by epifluorescence microscopy" published in Food
13 Microbiology, 1998, Vol. 15 discloses the capture of E. coli on
14 a polyvinylchloride sheet coated with polyclonal anti-E. coli
15 0157:H7 antibody and stained with fluorescein-labeled anti-E.
16 coli 0157:H7. After being scraped from the PVC surface, the
17 cells were subjected to epifluorescence microscopy for
18 determining presence and concentration. The reference fails to
19 teach or suggest the concept of incorporating any means for
20 self-detection within food packaging, nor does it contemplate
21 the inclusion of multiple means capable of both detecting and
22 identifying the source of pathogenic contamination to a
23 technically untrained end user, e.g. the food purchaser or
24 consumer, and especially fails to disclose such detection

1 without the use of specialized detection techniques and
2 equipment.

3 U.S. Patent 5,776,672 discloses a single stranded nucleic
4 acid probe having a base sequence complementary to the gene to
5 be detected which is immobilized onto the surface of an optical
6 fiber and then reacted with the gene sample denatured to a
7 single stranded form. The nucleic acid probe, hybridized with
8 the gene is detected by electrochemical or optical detection
9 methodology. In contrast to the instantly disclosed invention,
10 this reference does not suggest the immobilization of the probe
11 onto a flexible polyvinylchloride or polyolefin film, nor does
12 it suggest the utilization of gelcoats having varying
13 porosities to act as a control or limiting agent with respect
14 to the migration of antibodies or microbial material through
15 the bioassay test material, or to serve as a medium for
16 enhancement of the growth of the microbial material.

17 U.S. Patent 5,756,291 discloses a method of identifying
18 oligomer sequences. The method generates aptamers which are
19 capable of binding to serum factors and all surface molecules.
20 Complexation of the target molecules with a mixture of
21 nucleotides occurs under conditions wherein a complex is formed
22 with the specific binding sequences but not with the other
23 members of the oligonucleotide mixture. The reference fails to
24 suggest the immobilization of the aptamers upon a flexible

polyvinylchloride or polyolefin base material, nor does it suggest the use of a protective gelcoat layer which acts as a means to selectively control the migration of antibodies and antigens, or to serve as a medium for enhancement of the growth of microbial material.

Summary of the Invention

The present invention relates to packaging materials for food and other products, along with methods for their manufacture and use. The presence of undesirable biological materials in the packaged material is readily ascertained by the consumer, merchant, regulator, etc. under ordinary conditions and without the use of special equipment. A multiplicity of biological materials threaten our food supply. The present invention provides a unique composite material capable of detecting and identifying multiple biological materials within a single package. The biological material identification system is designed for incorporation into existing types of flexible packaging material such as polyvinylchloride and polyolefin films, and its introduction into the existing packaging infrastructure will require little or no change to present systems or procedures. Thus, the widespread inclusion of the biological material detecting system of the instant invention will be both efficient and

1 economical.

2 In one embodiment of the invention the biological material
3 detecting system prints a pattern containing several antibodies
4 or aptamers, derived from plant or animal origins, onto a
5 packaging material which is usually a type of polymeric film,
6 preferably a polyvinylchloride or polyolefin film and most
7 preferably a polyethylene film which has undergone a surface
8 treatment, e.g. corona discharge to enhance the film's ability
9 to immobilize the antibodies upon its surface. The agents are
10 protected by a special abrasion resistant gel coat in which the
11 porosity is tailored to control the ability of certain
12 antibodies, toxic substances, etc. to migrate therethrough.
13 Each antibody is specific to a particular biological material
14 and is printed having a distinctive icon shape. The detection
15 system may contain any number of antibodies capable of
16 detecting a variety of common toxic food microbes; although any
17 number of microbes may be identified via the inventive concept
18 taught herein, for the purpose of this description, the
19 microbes of interest will be limited to E.Coli, Salmonella,
20 Listeria and Cyclospora.

21 An important feature of the biological material detection
22 system is its all-encompassing presence around and upon the
23 product being packaged. Since the biological material
24 detecting system is designed as an integral part of 100% of the

packaging material and covers all surfaces as utilized, there is no part of the packaged product which can be exposed to undetected microbes. In the past, the use of single location or *in situ* detectors have left a majority of the area around and upon the packaged product exposed to undetected microbes. This greatly increased the chance that a spoiled or tainted product might be inadvertently consumed before the toxic agent had spread to the location of the *in situ* detector. The biological material detection system of the present invention avoids this problem by providing a plurality of individual detectors per unit area which are effective to insure positive detection of any pathogenic microorganisms within the product being tested. In order to be effective a particular degree of sensitivity is required, e.g. the detecting system must be capable of positively identifying one microbial cell in a 25 gram meat sample. In a preferred embodiment, four detectors per square inch of packaging material surface have been utilized, and in a most preferred embodiment nine or more detectors per square inch are incorporated upon the film's surface.

By use of the biological material detection system of the present invention a packager or processor can independently determine the multiplicity and identity of those biological materials against which the packaged product is to be

1 protected. Although it is envisioned that the large majority
2 of biological material detection treated packaging will be
3 generic to approximately four of the most common microbes, the
4 system will nevertheless allow each user to customize the
5 protection offered to the public.

6 The biological material detecting system will not merely
7 detect the presence of biological materials, it will also
8 identify the particular biological materials located in a
9 packaged product. This unique feature allows for the immediate
10 identification of each particular biological material present
11 since the antibodies are specific to a detector having a
12 definitive icon shape or other identifying characteristic.
13 Although the end use consumer is primarily interested in
14 whether a food product is, or is not, contaminated per se, the
15 ability to detect and identify the particular biological
16 material immediately is of immeasurable value to merchants,
17 processors, regulators and health officials. The ability to
18 immediately identify a toxic material will lead to greatly
19 reduced response times to health threats that might be caused
20 by the biological material and will also enhance the ability
21 for authorities to locate the source of the problem. The
22 biological material detecting system of the present invention
23 exhibits an active shelf life in excess of 1 year under normal
24 operating conditions. This enhances the use of a biological

1 material detection system on products which are intended to be
2 stored for long periods of time. If these products are stored
3 so as to be ready for immediate use in some time of emergency,
4 then it is extremely beneficial to definitely be able to
5 determine the safety of the product at the time that it is to
6 be used.

7 One particularly important feature of the biological
8 material detecting system of the instant invention is its
9 ability to quantitatively sensitize the reagents so as to
10 visually identify only those biological materials which have
11 reached a predetermined concentration or threshold level which
12 is deemed to be harmful to humans.

13 For example, almost all poultry meat contain traces of the
14 salmonella bacteria. In most cases, the salmonella levels have
15 not reached a harmful level of concentration. The biological
16 material detecting reagents are designed to visually report
17 only those instances where the level of concentration of
18 biological materials are deemed harmful by health regulatory
19 bodies.

20 The method of production of the biological material
21 detecting system is designed to be easily incorporated within
22 the packaging infrastructure of existing systems without
23 disruption of the systems or the procedures under which they
24 are operating. The biological material detecting system can be

1 incorporated onto packaging films which are produced by the
2 packager, or those which are supplied by a film manufacturer.
3 The apparatus necessary for applying the biological material
4 detecting system may be easily located at the beginning of any
5 continuous process such as printing or laminating and will
6 operate as an integral part of an existing system.

7 The biological material detecting system of the instant
8 invention represents an entirely new packaging material which
9 is designed to inform the consumer of the presence of certain
10 biological materials or pathogens present in food stuffs or
11 other materials packaged within the detecting system. The
12 system is designed so that the presence of a biological
13 material is presented to the consumer in a distinct,
14 unmistakable manner which is easily visible to the naked eye.

15 Recent outbreaks of E.Coli and other health hazards have
16 presented serious problems to the general population and have
17 raised concerns regarding the safety of the food supply.

18 It is an objective of the present invention to provide a
19 biological material detecting system for protecting the
20 consumer by detecting and unmistakably presenting to the
21 untrained eye visual icons on the packaging material which
22 signify the presence of a number of pathogens in the food stuff
23 or other materials which are at a level harmful to humans.

24 It is another objective of the instant invention to

1 provide a bioassay material wherein an antigen detecting
2 antibody system is immobilized upon the surface of a flexible
3 polyolefin film.

4 It is still another objective of the instant invention to
5 provide a bioassay material wherein an antigen detecting
6 antibody system is immobilized upon the surface of a flexible
7 polyvinylchloride film.

8 It is a further objective of the invention to provide a
9 biological material detecting system which is so similar in
10 appearance and utilization that its use, in lieu of traditional
11 packaging materials, is not apparent to the food processor or
12 other packagers.

13 A still further objective of the present invention is to
14 provide a biological material detecting system which is cost
15 effective when compared to traditional packaging materials.

16 It is still another objective of the present invention to
17 provide a biological assay material for protecting the consumer
18 by detecting and unmistakably presenting to the untrained eye
19 one or more visual icons on a packaging material which signify
20 the presence or absence of a particular toxic substance.

21 Other objectives and advantages of this invention will
22 become apparent from the following description taken in
23 conjunction with the accompanying drawings wherein are set
24 forth, by way of illustration and example, certain embodiments

of this invention. The drawings constitute a part of this specification and include exemplary embodiments of the present invention and illustrate various objects and features thereof.

Brief Description of the Figures

Figure 1 is a cross-sectional interpretation of an antibody sandwich immunoassay device;

Figure 2 is a cross-sectional interpretation of a single ligand assay;

Figure 2A is a cross-sectional interpretation of a single ligand assay including a chromogenic ligand;

Figure 3 is a diagrammatic representation showing the functioning of a single ligand assay;

Figure 4 is a cross-sectional interpretation of an antibody sandwich immunoassay including a scavenger system for microbial quantification;

Figures 5 and 6 are a diagrammatic representation showing the functioning of a sandwich assay/scavenger system;

Figure 7 is a planar view of an example of icon placement and printing;

Figure 7A is an example of a typical code of identification applied to the icon pattern;

Figure 8 is the result derived from EXAMPLE 2 and exemplifies capture sensitivity of a single ligand treated

1 Description of the Preferred Embodiment(s)

2 Referring now to Figure 1, the detection and
3 identification of various biological materials in packaged
4 foods or other products is accomplished by the use of
5 antibodies which are specific to the biological material being
6 sought. Specific antibodies, defined as capture antibodies,
7 are biologically active ligands characterized by their ability
8 to recognize an epitope of the particular toxic substance being
9 tested. These capture antibodies are selected from such
10 materials as antibodies, aptamers, single stranded nucleic acid
11 probes, lipids, natural receptors, lectins, carbohydrates and
12 proteins. In one embodiment of the invention, the capture
13 antibodies are arranged with unique icon shapes and in
14 particular patterns. The capture antibodies are immobilized to
15 the polymer film. An agarose gel coat containing detector
16 antibodies is printed in register above the capture antibodies.
17 A protective gel coat completes the construction of the
18 packaging material. The gel coat constituting the inner layer,
19 e.g. that layer which is next to the packaged product, is a
20 special type of gel coat or an equivalent thereto which has
21 sufficient porosity to allow toxic molecules, known as
22 antigens, to migrate through it to an antibody "sandwich"
23 laminated between the polymer film and the gel coat. The
24 special gel coat has sufficient abrasion resistance to prevent

1 exposure of the reagents to the product. The special gel coat
 2 useful in the invention is a readily available coating commonly
 3 utilized in the food industry to coat candies and the like,
 4 e.g. coated chocolates to prevent them from melting on one's
 5 hands. Migration of antigens is driven by capillary action and
 6 normally reaches a state of equilibrium within a 72 hour time
 7 period. In a particularly preferred embodiment, when operating
 8 within a temperature range of 4 - 25 degrees Celsius, an
 9 initial positive reading can be obtained within 30 minutes, and
 10 the test continues to yield results for about 72 hours. Upon
 11 migrating through the special gel coat the antigen enters an
 12 agarose gel film which has surfactant properties, contains free
 13 detector antibodies, and also contains one or more ingredients
 14 designed to enhance the growth of microbial materials, e.g.
 15 nutrients such as sorbitol, NOVOBIOCIN, CEFIXIME and TELLURITE
 16 which increase the growth rate and ease isolation of E. Coli
 17 0157H. If the antigen encounters a species of antibody which
 18 is specific to an epitope thereof, it will then bind to it
 19 forming a detector/antibody complex. Once bound thereto, the
 20 bound antigen/antibody complex becomes too large to migrate
 21 back through the special gel coat due to its inherent fine
 22 porous structure. This insures that pathogenic material can
 23 not migrate back into the product being tested. Continuing
 24 pressure toward equilibrium from capillarity will tend to move

1 on the number of antibodies that can be utilized in a single
2 biological material detecting system.

3 As demonstrated in Figures 7 and 7A, the invention is
4 exemplified with reference to detection of the following four
5 microbes:

- 6 1. E-Coli;
- 7 2. Salmonella;
- 8 3. Listeria; and
- 9 4. Cyclospora.

10 To each of the four microbes, a particular icon shape is
11 assigned. Although there are infinite numbers of icons which
12 might be used including letters, numbers, or even words, we
13 have chosen simple identifiers for the purpose of
14 demonstration. As an initial step in the construction of the
15 biological material detecting system, the outer polymer film or
16 base layer undergoes a printing process in which a pattern of
17 the four icons, wherein each icon utilizes a specific species
18 of immobilized capture antibody, is applied thereto.
19 Corresponding species of free antibodies, known as detector
20 antibodies, which are biologically active ligands characterized
21 by their ability to recognize a different epitope of the same
22 particular toxic substance being tested for, and suspended in
23 an agarose gel solution containing a surfactant and a nutrient,
24 are printed in registration with the immobilized antibodies so

1 as to be in overlying and juxtaposed relationship thereto, and
2 are then dried. Lastly, a second gel coat having a degree of
3 porosity sufficient to prevent passage of the detector
4 antibodies is laminated to the preparation.

5 Although the detection of biological materials through the
6 use of antibodies is well known, there are several new and
7 novel aspects to the application of antibody science which are
8 set forth in the development of the biological material
9 detecting system of the present invention.

10 Among these are: 1) the use of multiple antibodies to
11 detect multiple biological materials in individual packages; 2)
12 the use of a distinctive icon or other shape to not only
13 detect, but visually identify the biological materials to the
14 consumer, vendor, regulator, etc.; 3) insuring that detection
15 and identification of the biological materials is accomplished
16 in a timely manner in each particular application by
17 judiciously controlling the porosity of the gel coat, thereby
18 controlling the lapse rate of the reaction through the strength
19 of capillary action; 4) inclusion of additives within the
20 special gel coat to enhance the levels of microbes present; 5)
21 incorporating the biological material detecting system of the
22 instant invention within the existing packaging industry
23 infrastructure; and 6) providing a bioassay material and
24 methods for its production and use which immobilizes the

1 antibodies onto the surface of a flexible polyvinylchloride or
2 polyolefin, e.g. a polyethylene, a surface treated
3 polyethylene, a polypropylene, a surface treated polypropylene
4 or mixture thereof.

5 The embodiment discussed above is based upon a sandwich
6 immunoassay as depicted in Figure 1, which measures specific
7 microbes, wherein the particular toxic substance is one or more
8 members selected from the group consisting of a particular
9 microorganism or species thereof, biological materials
10 containing the genetic characteristics of said particular
11 microorganism, and mutations thereof. In a particular
12 embodiment, the toxic substance is selected from the group
13 consisting of microorganisms, nucleic acids, proteins, integral
14 components of microorganisms and combinations thereof.

15 It should also be understood that the invention will
16 function by direct measurement of microbes with certain types
17 of antibodies, selected from the group consisting of an
18 antibody, a single stranded nucleic acid probe, an aptamer, a
19 lipid, a natural receptor, a lectin, a carbohydrate and a
20 protein. The biological materials may also be measured by non-
21 immunological methods in particular using labeled molecules,
22 such as aptamers, which have a high affinity for the biological
23 materials.

24 The invention utilizes various types of detector

antibodies, e.g. those conjugated with dyes to produce a visual cue, or alternatively, photoactive compounds capable of producing a visual cue in response to a particular type of light exposure, for example a scanning system which detects luminescent properties which are visualized upon binding of the antigen and antibody. In this method of construction biological materials are measured directly with a biologically active ligand, e.g. an antibody, aptamer, nucleic acid probe or the like, which induces a conformational change to produce a visual cue.

It is also understood that specific polymers may be incorporated into the invention and that when a biological material is bound to the surface it induces a molecular change in the polymer resulting in a distinctly colored icon.

Referring to Figures 2 and 2A, in an alternative embodiment, a sandwich-type of construction is not necessary. As depicted in Figures 2 and 2A, the provision of certain types of biologically active ligand, e.g. chromogenic ligands to which receptors are bound will permit the visual confirmation of binding of the antigen to the immobilized ligand.

As depicted in Figure 3, a polymer film is provided and a biologically active ligand, preferably a chromogenic ligand, is immobilized to the polymer film. In the past, immobilized ligands were attached to rigid solid support matrices such as

1 plastic, polystyrene beads, microtitre plates, latex beads,
2 fibers, metal and glass surfaces and the like. The immobilized
3 ligands have also been attached to flexible surfaces such as
4 nitrocellulose or polyester sheets which were not transparent.
5 Surprisingly, the inventor has discovered that it is possible
6 to attach biologically active ligands to the surface of various
7 flexible polymeric films, for example polyvinylchloride and
8 polyolefins, e.g. a polyolefin sheet having appropriate
9 properties of transparency and flexibility and that the
10 composite functions as a biological sensor or assay material.
11 After printing on the polymer film, the material goes through
12 a drying step; subsequent to which a special gel coat or liquid
13 film is applied as a protectant layer and the final product is
14 then dried.

15 Illustrative of films which will function in the present
16 invention is a film containing a structural polymer base having
17 a treated surface and incorporating therein a fluorescing
18 antibody receptor and finally a stabilized gel coat. These
19 films may be untreated polyethylene or polyvinylchloride films
20 which are amenable to antibody immobilization by various
21 mechanisms, e.g. by adsorption. In a particular embodiment,
22 the films may be first cleaned, e.g. by ultrasonication in an
23 appropriate solvent, and subsequently dried. For example, the
24 polymer sheet may be exposed to a fifteen minute ultrasonic

1 treatment in a solvent such as methylene chloride, acetone,
2 distilled water, or the like. In some cases, a series of
3 solvent treatments are performed. Subsequently, the film is
4 placed in a desiccating device and dried. Alternatively, these
5 films may be created by first exposing the film to an electron
6 discharge treatment at the surface thereof, then printing with
7 a fluorescing antibody receptor. Subsequently, a drying or
8 heating step may be utilized to treat the film to immobilize
9 the receptor. Next, the film is washed to remove un-
10 immobilized receptor; the film is then coated with a gel and
11 finally dried.

12 Additional modifications to polyolefin films may be
13 conducted to create the presence of functional groups, for
14 example a polyethylene sheet may be halogenated by a free
15 radical substitution mechanism, e.g. bromination,
16 chlorosulfonation,, chlorophosphorylation or the like.
17 Furthermore, a halodialkylammonium salt in a sulfuric acid
18 solution may be useful as a halogenating agent when enhanced
19 surface selectivity is desirable.

20 Grafting techniques are also contemplated wherein hydrogen
21 abstraction by transient free radicals or free radical
22 equivalents generated in the vapor or gas phase is conducted.
23 Grafting by various alternative means such as irradiation,
24 various means of surface modification, polyolefin oxidation,

1 acid etching, inclusion of chemical additive compounds to the
2 polymer formulation which have the ability to modify the
3 surface characteristics thereof, or equivalent techniques are
4 all contemplated by this invention.

5 Additionally, the formation of oxygenated surface groups
6 such as hydroxyl, carbonyl and carboxyl groups via a flame
7 treatment surface modification technique is contemplated.

8 Further, functionalization without chain scission by
9 carbene insertion chemistry is also contemplated as a means of
10 polyolefin polymer modification.

11 Illustrative of the types of commercially available films
12 which might be utilized are polyvinylchloride films and a
13 straight polyethylene film with electron discharge treatment
14 marketed under the trademark SCLAIR®. The electron discharge
15 treatment, when utilized, renders the film much more
16 susceptible to immobilization of the antibodies on its surface.
17 Additional films which might be utilized are Nylon 66 films,
18 for example DARTEK®, a coextrudable adhesive film such as
19 BYNEL® and a blend of BYNEL® with polyethylene film.

20 With reference to Figures 4-6, one of the most important
21 features of the biological material detecting system is its
22 ability to quantitatively sensitize the antibody or aptamer so
23 as to visually identify only those biological materials that
24 have reached a concentration level deemed harmful to humans.

1 One means of providing this sensitization is by including a
2 scavenger antibody which is a biologically active ligand
3 characterized as having a higher affinity for the particular
4 toxic substance than the capture antibody. The scavenger
5 antibody is provided in a sufficient amount to bind with the
6 particular toxic substance up to and including a specific
7 threshold concentration. In this manner, the capture antibody
8 will be prevented from binding with a detector antibody until
9 the concentration of the particular biological material
10 surpasses the specific threshold concentration. In this
11 manner, the biological material detecting system visually
12 reports only those instances where concentration levels are
13 deemed harmful by health regulatory bodies.

14 Since the biological material detecting system as
15 described herein can maintain its activity over long periods of
16 time, e.g. up to 1 year, it is able to protect against
17 contamination in products which have long shelf lives.
18 Additionally, by reporting only toxic concentrations, it avoids
19 "false positives" and, in some cases, can extend the useful
20 life of the product.

21 Referring to Figures 9 and 10, the apparatus for producing
22 the biological material detecting system is illustrated. These
23 embodiments are essentially particular combinations of
24 printers, coaters and dryers which will be used to place

biologically active reagents upon a thin polymer film useful for packaging food stuffs and other products. These films will be further processed subsequent to application of the biological material detecting system by printing, laminating, or equivalent methods of fabrication. The machinery is designed so that it will transport and process very thin films at rather high speeds. Furthermore, the machinery is designed so that it can be utilized effectively as an additional processing step when added to continuous processing operations already in use at packaging material fabrication plants. The printing machinery is designed so that a minimum of four distinct biological active ligands in a hydrate solution can be printed in patterns in a precise registration on the polymer film. The printing may be accomplished by jet spray or roller application, or equivalent printing methods. Each print applicator is capable of printing a detailed icon no larger than 1/4" x 1/4" in a minimum thickness. Patterning may be controlled by computer or roller calendaring. It is important to determine the appropriate viscosity of the solution to be applied so that successful printing, coating, and drying can be accomplished. After the printing step, the icons must be protected. This is accomplished by a final application of a thin special gel coat or a thin liquid film. By way of example, the liquid film may be an overprint food varnish.

This step is accomplished by a 100% coating of the entire film or alternatively by selectively coating each icon such that a 10% overlap is coated beyond the icon in all directions. This coating step may be accomplished with sprays or rollers and the viscosity of the coating material must be optimized so as to provide adequate coverage. The biological material detecting system must be dried after printing and once again after coating. The drying is accomplished in a very rapid manner, so as to enable high through put for the process. Various means of drying include the use of radiant heat, convected air and freeze drying. Care must be taken to avoid drying temperatures which will inactivate the biological reagents which have been applied. The polymer film which has been surface treated in the form of electron discharge, e.g. corona treatment, is most preferred. After preparation, the thin film is transported at relatively high speeds so that a wrinkle free surface is provided for printing, coating and rollup. Additionally, the apparatus provides a complete recovery system for the reagents which allows for total recovery of the agents and the volatile organic contaminants.

The invention will be further illustrated by way of the following examples:

EXAMPLE 1

Detection of Antibody on the Surface of a Thin Layer

Polyvinylchloride Sheet:

Rabbit polyclonal IgG was diluted to a final concentration of 2.0 µg/ml in 0.1M carbonate (Na_2CO_3)-bicarbonate (NaHCO_3) buffer, pH 9.6.

Using a 2" x 3" grid, 75 µL (150 ng) was applied to a sheet of polyvinylchloride at 1" intervals.

The antibody treated polyvinylchloride sheet was dried for 1.5 hours at a temperature of 37°C.

The dried sheet was then washed 3 times with a phosphate buffered saline solution at a pH of 7.4.

HRP conjugated goat anti-rabbit IgG ($\text{G}\alpha\text{R}^{\text{HRP}}$) was diluted to a concentration of 1:7000 in 1% casein, 0.1M potassium ferricyanide $\text{K}_3\text{Fe}(\text{CN})_6$, 0.1% phosphate glass ($\text{Na}_{15}\text{P}_{13}\text{O}_{40}$ - $\text{Na}_{20}\text{P}_{18}\text{O}_{55}$), at a pH of 7.4.

A precision pipette was used to apply 125 µL of diluted G^{HRP} to the grid backed polyvinylchloride sheet at 1" intervals coinciding with the area covered by the previously coupled $\text{R}\alpha\text{G}$. The sheet was incubated at room temperature for 30 minutes.

The sheet was then washed 3 times with phosphate buffered saline at a pH of 7.4.

To the test areas, 125µL of precipitating TMB enzyme substrate was added.

The sheet was incubated at room temperature until color development was complete.

1 Lastly, the sheet was washed 3 times with deionized water
2 and allowed to air dry.

3 **EXAMPLE 2**

4 **Full Sandwich Immunoassay on the Surface of a Thin Layer** 5 **Polyvinylchloride Sheet:**

6 Rabbit polyclonal IgG was diluted to a final concentration
7 of 2.0 µg/ml in 0.1M carbonate (Na₂CO₃)-bicarbonate (NaHCO₃)
8 buffer, pH 9.6.

9 A 13 x 9 cm piece of thin layered polyvinylchloride sheet
10 was inserted into a BIO-RAD DOT-SPOT apparatus possessing 96
11 sample wells spaced at 1.0 cm intervals in a 12 x 8 well grid.

12 A 100 µL sample (1.0 µg) of rabbit polyclonal IgG was
13 applied to each well of column 1 (8 wells total).

14 Antibody samples applied to columns 2-12 represented
15 serial dilutions of the antibody ranging from 500 ng - 0.5 ng.

16 The antibody treated polyvinylchloride sheet was dried
17 overnight at 37° C.

18 The dried sheet was washed 3 times with phosphate buffered
19 saline (PBS), pH 7.4.

20 The antigen was diluted to a final concentration of 1.0
21 µg/ml in TRIS buffered saline (TBS) with 1% casein, pH 7.4.

22 Applied to each well of the apparatus was 100 µL,
23 representing 100 ng, of antigen, which was subsequently
24 incubated at room temperature for 1 hour.

1 The polyvinylchloride sheet was washed 3 times with
2 phosphate buffered saline (PBS), pH 7.4.

3 Detector mouse monoclonal antibody was diluted 1:625 with
4 TBS containing 1% casein, 0.1M potassium ferricyanide $K_3Fe(Cn)_6$,
5 and 0.1% phosphate glass ($Na_{15}P_{13}O_{40} - Na_{20}P_{18}O_{55}$), pH 7.4.

6 To each well of row 1, 100 μ L of the 1:625 dilution of
7 detector antibody solution was applied.

8 Detector samples of 100 μ L applied to rows 2-7 represented
9 serial dilutions of the antibody ranging from 1:1,250 to
10 1:80,000. Dilutions of detector antibody were incubated on the
11 polyvinylchloride sheet for 1 hour at room temperature.

12 The polyvinylchloride sheet was washed 3 times with
13 phosphate buffered saline (PBS), pH 7.4.

14 To each well of the DOT-SPOT apparatus, 100 μ L of goat
15 anti-mouse IgG^{HRP} was added and allowed to incubate for one hour
16 at room temperature.

17 The polyvinylchloride sheet was washed 3 times with
18 phosphate buffered saline (PBS), pH 7.4.

19 To the test areas 100 μ L of precipitating TMB enzyme
20 substrate was added.

21 The sheet was incubated at room temperature until color
22 development was complete (see Figure 8).

23 Lastly, the sheet was washed 3 times with deionized water
24 and allowed to air dry.

EXAMPLE 3

Half Sandwich Competitive Immunoassay on the Surface of a Thin Layer Polyvinylchloride Sheet:

In this example, the printing of an icon shape is employed, such as an "X" 132, illustrated in Figure 13A. The icon is printed overlying a flexible film base layer 110, having two surfaces, prepared as previously described. A first layer 112 in an icon shape containing an overprint food varnish in combination with a capture antibody, referred to as a biologically active ligand, is printed over one surface of the base layer 110 to allow the immobilization of the biologically active ligand 120 to the surface of the film 110. A second layer 114, in register with the first 112, containing a buffer medium comprising a dye conjugated to a peptide 122, wherein the biologically active ligand has a degree of affinity for the peptide, is printed over the first layer 112 to allow contact for the peptide/dye conjugate 122 to bind to the immobilized ligand 120 (Figure 11) forming a homogeneous conjugate blend 124. At this point, the area printed on the film appears colored. The dye chosen for this example is a food dye giving a blue coloration, and therefore a blue "X" 132 is visualized (Figure 13A).

In a further example, an overprint food varnish in combination with a biologically active ligand is placed in

1 contact with a dye conjugated to a peptide to form a
2 homogeneous conjugate blend 124 as the peptide binds to the
3 biologically active ligand. A single layer 116 in an icon
4 shape of the homogeneous conjugate blend may be printed onto a
5 flexible film 110. Thus, as in Figure 12, a second layer
6 introducing the peptide/dye conjugate is not required.

7 The antigen, a particular toxic substance 128, being
8 sought is competitive with the peptide conjugating the food dye
9 for binding to the immobilized biologically active ligand. As
10 illustrated in Figures 15A, 15B, and 15C, when the antigen 128
11 comes in contact with the biologically active ligand (Figure
12 15A) having a degree of affinity for a particular toxic
13 substance greater than that for the peptide, the antigen
14 displaces the peptide, releasing the peptide/food dye conjugate
15 122 (Figure 15B), thereby exhibiting loss of color within the
16 icon "X" 134 (Figure 13B). As the peptide/dye conjugate is
17 displaced, the particular toxic substance binds to the
18 immobilized ligand 150 (Figure 15C) producing a visual signal,
19 in this case loss of coloration within the "X", which is
20 indicative of both the presence and identity of the particular
21 toxic substance. So, when placing the flexible film in an
22 environment which may contain a particular toxic substance,
23 loss of coloration exhibited gives the user a visual cue to
24 determine if the particular toxic substance is present. If no

1 loss of color is exhibited, the particular toxic substance is
2 absent. The user may also monitor the film for a period of
3 time sufficient to observe a visual signal in order to
4 determine the length of time necessary before the particular
5 toxic substance reaches a level deemed unfit for consumption.

6 Alternatively, the parts needed to make a second icon
7 shape, such as a circle 140 surrounding the "X" 132 to a
8 sufficient degree as to render the first icon shape invisible,
9 comprising the peptide conjugated food dye in a layer, may be
10 printed directly onto a flexible polymer film 110. Referring
11 to Figure 14A, when surrounding the icon "X" 132 chosen with
12 the same dye/peptide conjugate, the "X" is not visualized.
13 Thus, when the antigen displaces the peptide and loss of color
14 within the area of the "X" 134 occurs, the image will appear as
15 a blue circle 140 with a white or colorless "X" 134 through or
16 within it (Figure 14B).

17 Any type of dye may be chosen that is approved for use
18 with food products. In addition, more than one biologically
19 active ligand may be utilized and more than one peptide may be
20 utilized. Once the peptide/dye conjugate is allowed to bind to
21 the immobilized ligand, the area may be washed to remove any
22 excess conjugate not bound by the ligand. A liquid film may
23 also be applied as a protectant layer covering the homogeneous
24 conjugate blend. Also, when incorporating a second icon shape,

1 a second dye may be utilized within the first icon shape, while
2 still using a first dye, in order to create a visual signal in
3 absence of a particular toxic substance and, in the presence of
4 a particular toxic substance, create a visual color change
5 within the first icon shape.

6 All patents and publications mentioned in this
7 specification are indicative of the levels of those skilled in
8 the art to which the invention pertains. All patents and
9 publications are herein incorporated by reference to the same
10 extent as if each individual publication was specifically and
11 individually indicated to be incorporated by reference.

12 It is to be understood that while a certain form of the
13 invention is illustrated, it is not to be limited to the
14 specific form or arrangement herein described and shown. It
15 will be apparent to those skilled in the art that various
16 changes may be made without departing from the scope of the
17 invention and the invention is not to be considered limited to
18 what is shown and described in the specification and
19 drawings/figures.

20 One skilled in the art will readily appreciate that the
21 present invention is well adapted to carry out the objectives
22 and obtain the ends and advantages mentioned, as well as those
23 inherent therein. The embodiments, methods, procedures and
24 techniques described herein are presently representative of the

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1 preferred embodiments, are intended to be exemplary and are not
2 intended as limitations on the scope. Changes therein and other
3 uses will occur to those skilled in the art which are
4 encompassed within the spirit of the invention and are defined
5 by the scope of the appended claims. Although the invention
6 has been described in connection with specific preferred
7 embodiments, it should be understood that the invention as
8 claimed should not be unduly limited to such specific
9 embodiments. Indeed, various modifications of the described
10 modes for carrying out the invention which are obvious to those
11 skilled in the art are intended to be within the scope of the
12 following claims.